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Milling properties of *desi* and *kabuli* chickpea (*Cicer arietinum*) varieties released in India

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ABSTRACT

Dal milling is among top three grain processing industries in India. Milling performance of pulses varies with grain property and milling methodologies with a key role played by the genotype. More than 190 varieties of chickpea belonging to both *desi* and *kabuli* types have been released in India mainly on the basis of yield and disease reaction, ignoring the miller and traders preferred processing traits. There is dearth of information about milling performance of chickpea varieties cultivated in India. The present study provides milling potential of 46 popular chickpea varieties which are currently in seed chain in the country. Although *kabuli* type chickpea varieties are mostly consumed as whole seed, yet they were included in the study for comparing their milling potential with *desi* types. The *kabuli* varieties exhibited better *dal* recovery (83.1-87.8%) than *desi* (61.3-82.6%) along with lesser soaking period (90-240 min) and chaff content (8-13.6%) due to their thinner seed coat. The *kabuli* types exhibited poor grain yield (944-1764 kg/ha) as compared to *desi* types (811-2558 kg/ha). The difference in yield among *desi* and *kabuli* types was compensated in dal yield to some extent due to better dal recovery (%) among *kabuli* types. Among *desi* varieties, soaking period and chaff content was positively correlated indicating that more the chaff content more will be the soaking duration and vice versa. The *dal* recovery was positively correlated with 100-seed weight and negatively correlated with chaff content. *Dal* recovery among *desi* varieties can be improved by reducing seed coat thickness. *Desi* varieties GNG-2144, RSG-963, RSG-974 and *kabuli* varieties IPCK 2002-29, CSJK-6, JGK-3 exhibited better milling propertiesand can be used as a donor for improved milling properties.

Key words: Chickpea, Correlation, Milling properties, 100 Seed weight,

India is the largest producer (17.15 m tonnes), consumer (21.51 m tonnes) and importer (4.58 m tonnes) of pulses in the world (DAC and FW 2016). It is also the largest pulses processor owing to poor pulse processing facilities in the major exporter countries like Myanmar, Canada and Australia (Gowda *et al*. 2013). Chickpea is the most important pulse crop in India accounting for nearly 44% (7.48 m tonnes) of the total pulse production (17.06 m tonnes) and 86% of total pulse export during 2015-16 (DAC and FW 2016). It is a good source of carbohydrates and protein which accounts for about 80% of the total dry seed mass (Geervani 1991, Chibbar *et al*. 2010) and constitutes an important component of diet of largely vegetarian Indian masses. Chickpea seed has high digestible protein and complex carbohydrate with low glycemic index and is relatively free from anti-nutritional factors (Muzquiz and Wood 2007, Wood and Grusak 2007). Chickpea protein complements cereal based diet with several essential amino acids.

There are two distinct types of chickpea, *desi* (microsperma) and *kabuli* (macrosperma) type. The *desi* types typically have pink flowers with anthocyanin pigmentation on stems and produces small and coloured seeds having thick seed coat. On the other hand, *kabuli* types mostly have white flowers and lack anthocyanin pigmentation on stems producing white or beige coloured large ram's head shaped smooth seeds having thin seed coat (Tripathi *et al*. 2012).

Indian sub-continent is the major chickpea producing region where 85-90% of *desi*-type chickpeas are milled prior to consumption either as *dal* (split cotyledon) or *besan* (grounded flour) that is used to prepare different snacks (Chavan *et al*. 1986, Hulse 1991). *Kabuli* types are mostly used for table purpose. *Dal* milling has been ranked third largest grain-processing industry in India, next only to rice and wheat milling (Ali 2003). Many factors affect the milling performance of pulses like genotype, quality of seed, seed moisture, milling equipments and methodology, pre-milling treatment *etc* (Kulkarni 1993, Wood and Malcolmson 2011). Among these, genotypes have a profound effect on milling performance (Wood *et al*. 2008). Although the need for developing genotypes with higher milling efficiency and optimising milling yields is generally accepted, not much have been reported on the

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same. A few studies do report milling parameters but are confined to few genotypes (Chavan *et al*. 1993, Singh *et al*. 1999, Burridge *et al*. 2001). In the present study, an attempt was made to analyse the milling performance of 46 popular chickpea varieties cultivated in India.

MATERIALS AND METHODS

The present study comprised of 46 chickpea varieties released for cultivation in India (Table 1). These include 38 *desi* and 8 *kabuli* type varieties which are presently in the national breeder seed production chain. The experiment was laid in a randomized complete block design with three replications in a 7.5 m^2 plot following spacing of 30 cm between rows and 10 cm between plants at ICAR-Indian Institute of Pulses Research (IIPR), Kanpur farm during 2015-16. Observations were recorded on yield per plot which was utilised to calculate grain yield/ha. Freshly harvested chickpea grains were allowed to dry naturally to a moisture content of 10-12% and then observations were recorded on 100 seed weight and samples were collected for milling. The chickpea varieties were processed in the Mini-*dal* mill at ICAR-IIPR, Kanpur (Lal and Verma 2007). The milling process involved removal of dust particles, chaff or any other foreign matter from chickpea seeds. The cleaned seed were pre-treated by soaking in water and drying in the sun for loosening of husk from the cotyledons which was attached through a gum layer. This facilitates dehusking and splitting the cotyledons with less breakage. The seed

Table 1 Description of 46 chickpea varieties/lines used in the study

Variety/ Genotype	Year of release	Pedigree	Features
Raj Vijay Gram 202 (RVG 202)	2015	(JAKI 9226 × DCP 20) × JG 412	*Desi* variety for late sown cultivation in CZ.
Raj Vijay Gram 203 (RVG 203)	2012	(ICCV 91902 × ICCV 10) × ICCV 89230	*Desi* variety for irrigated and late sown cultivations in CZ.
GLK 26155 (L 555)	2012	BG 1088 × MPJG 2	*Kabuli* variety for irrigated cultivation in NWPZ.
CSJ 515	2013	FG 712 × CSJ 146	*Desi* variety for irrigated cultivation in NWPZ.
GNG 1958	2013	GNG 1365 × SAKI 9516	*Desi* variety for irrigated cultivation in NWPZ.
Anvita (RSG 931)	2004	RSG 44 × RSG 524	Double podded *desi* variety for rainfed cultivation in NWPZ.
PBG 5	2012	BG 257 × Narsinghpur bold	*Desi* variety for both irrigated and rainfed cultivation in Punjab.
Raj Vijay Gram 201 (RVG 201)	2012	PG 5 × Bheema	*Desi* variety for irrigated cultivation in Madhya Pradesh.
PKV *Kabuli* 4	2010	Selection from germplasm	Extra large seeded *kabuli* variety for irrigated cultivation in Maharashtra and Madhya Pradesh.
Abhilasha (RSG 974)	2011	K 850 × RSG 515	*Desi* variety for rainfed and late sowing in Rajasthan.
Kripa (Phule G 0517)	2010	Selection from local germplasm	Extra large seeded *kabuli* variety for irrigated cultivation in Maharashtra, Madhya Pradesh and Karnataka.
Shubhra (IPCK 2002-29)	2009	L 144 × H 82-2	Large seeded *kabuli* variety for irrigated cultivations in CZ.
Ganguar (GNG 1581)	2008	GPF 2 × H 82-2	*Desi* variety for irrigated cultivation in NWPZ.
Digvijay	2007	Phule G 91028 × Bheema	*Desi* variety for rainfed cultivation in Maharashtra.
JAKI 9218	1997/ 2008	(ICCV 37 × GW 5/7) × ICCV 107	*Desi* variety for rainfed cultivation in CZ.
Gujarat Junagadh Gram 3 (JGK 3)	2010	ICCV 933001 × ICCV 10	*Kabuli* variety for rainfed cultivation in Gujarat.
Abah (RSG 973)	2006	RSG 515 × K 850	*Desi* variety for rainfed cultivation in Rajasthan.
Pusa 547 (BGM 547)	2006	Mutant of BG 256	*Desi* variety for irrigated cultivation in NWPZ.
Haryana Kabuli Chana 2 (HK 2)	2005	(H 82-5 × E100 Ym) × Bheema	*Kabuli* variety for irrigated cultivation in NEPZ.
Arpita (RSG 895)	2005	RSG 44 × RSG 255	*Desi* variety for rainfed cultivation in Rajasthan.
Aadhar (RSG 963)	2005	RSG 524 × PDG 84-10	*Desi* variety for rainfed cultivation in NWPZ.
Asha (RSG 945)	2005	RSG 668 × RSG 817	*Desi* variety for rainfed cultivation in Rajasthan.
Haryana Chana 5 (HC 5)	2005	H 89-78 × H 89-84	*Desi* variety for irrigated and rainfed cultivation in Haryana.

Cond.

Table 1 (*Concluded*)

Variety/ Genotype	Year of release	Pedigree	Features
Anubhav (RSG 888)	2003	RSG 44 × E 100 Y	*Desi* variety for rainfed cultivation in NWPZ.
Jawahar Gram 130 (JG 130)	2002	(Phule G 5 × Narsinghpur bold) × JG 74	*Desi* variety for irrigated and rainfed cultivation inMadhya Pradesh.
SAKI 9516 (JG 16)	2001	ICCC 4 × ICCV 10	*Desi* variety for Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Rajasthan.
PKV Kabuli 2 (KAK 2)	2001	(ICCC 2 × Surutato 77) × ICC 7344-ICC× 870026-PB-PB-14P-BP-62AK-7AK-BAK	Large seeded *kabuli* variety for irrigated cultivations in Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Rajasthan.
Gujarat Gram 1	1999	GCP 2 × ICCV 2	*Desi* variety for rainfed cultivations in CZ.
Gujarat Gram 2	2003	JG 1258 × BDN 9-3	*Desi* variety for rainfed cultivations in Gujarat.
JG 11	1999	[(Phule G 5 × Narsinghpur bold) × ICCC 37] ICCX-860263-BF-BP-91 BP	*Desi* variety for irrigated and rainfed cultivations in SZ.
Samrat (GNG 469)	1997	Annegeri1 × H 75-35	*Desi* variety for rainfed and irrigated cultivations in Rajasthan, Punjab and Haryana.
GPF 2	1990/ 2010	GL 769 × H 75-35	*Desi* variety for irrigated cultivations in NWPZ.
Vijay	1994	P 127 × Annegeri 1	*Desi* variety for rainfed cultivations in NWPZ, NEPZ and CZ.
JG 315	1984	Selection from WR 315	*Desi* variety for rainfed cultivations in NWPZ and CZ.
Annegeri 1	1978	Local selection from germplasm	*Desi* variety for rainfed cultivations in Karnataka.
C 235	1975	IP 58 × C 1234	*Desi* variety for rainfed cultivations in Punjab and Haryana.
Aruna (RSG 902)	2007	RSG 44 × PDG 84-10	Double podded *desi* variety for rainfed cultivations in Rajasthan.
Vishal	1997	K 850 × ICCL 80074	*Desi* variety for rainfed cultivations in Maharashtra.
GNG 2144	2016	CSJD 901 × CSG 8962.	*Desi* variety for late sown cultivations in NWPZ.
N BeG 47		ICCV 2 × PDG 84-16	*Desi* variety amenable to mechanical harvesting and cultivation in Andhra Pradesh.
GBM 2		Mutant of chickpea variety Annegiri 1	*Desi* variety amenable to mechanical harvesting and cultivation in Karnataka.
CSJK 6	2012	RSGK 628 × BG 1053	*Kabuli* variety suitable for timely planting under irrigated cultivation in NHZ.
Sadabahar	1992	Hima × L 245	Green seeded *desi* variety for irrigated cultivations in Uttar Pradesh.
Aparna (RSG 991)	2007	RSG 289 × BG 1053	*Desi* variety for late and timely planting under rainfed cultivations in Rajasthan.
Karnal Chana 1 (CSG 8962)	1998	Selection from GPF 7035	Salt tolerant *desi* variety suitable for planting under rainfed cultivation in NWPZ.
GNG 2171		GNG 663 × BG 1044	Small seeded *desi* line for timely planting under irrigated cultivations in NWPZ.

NHZ, Northern hill zone (Jammu and Kashmir, Himachal Pradesh, Uttarakhand and NEH region); NEPZ, North east plain zone (Eastern Uttar Pradesh, West Bengal, Jharkhand, Bihar and North East states); NWPZ, North west plain zone (North West Rajasthan, Punjab, Haryana, Western Uttar Pradesh, Uttarakhand and Delhi); CZ, Central Zone (Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, and Southern Rajasthan); SZ, South Zone (Karnataka, Andhra Pradesh & Tamil Nadu).

was passed through the *dal*-mill and typically the husk was removed and the grain was split into *dal*. After milling, split cotyledons (*dal*), husk, broken grains and powder were obtained. Two Kilogram seed of each variety was used for milling. During milling, observations were recorded on soaking duration, *dal* recovery (%) and chaff (%). The *dal* yield (kg/ha) was calculated based on grain yield (kg/ha) and *dal* recovery (%) of a variety.

$$Dal\ \text{recovery}\ (\%) = \frac{Dal\ \text{yield after milling (kg)}}{\text{Quantity of grain milled (kg)}} \times 100$$

$$\text{Chaff recovery}\ (\%) = \frac{\text{Chaff yield after milling (kg)}}{\text{Quantity of grain milled (kg)}} \times 100$$

$$Dal\ \text{yield}\ (\%) = \frac{\text{Grain yield (kg/ha)} \times Dal\ \text{recovery}\ (\%)}{100}$$

Genetic parameters, viz. mean, range, genotypic and phenotypic coefficients of variations, heritability, genetic advance and correlations were estimated according to Singh and Chaudhary (1977).

RESULTS AND DISCUSSION

Large variation was observed among genotypes in both *desi* and *kabuli* varieties for all the traits under study. Overall, the *kabuli* varieties exhibited relatively better milling recovery than the *desi* varieties. The *kabuli* varieties took lesser soaking period, thus significantly reducing the duration of milling. They have less chaff content hence show better *dal* recovery. Although the yield potential of *kabuli* varieties was lesser than *desi* varieties yet the increased *dal* recovery helped in better realization from the harvest. The larger seed size of *kabuli* types further aided in better *dal* recovery although quality of milled produce among *kabuli* types was poor.

Soaking duration

The soaking duration among *desi* varieties ranged from 120-360 min with average soaking duration of 233.8 min while that of *kabuli* varieties ranged from 90-240 min with mean value of 125 min (Table 2). Such difference among soaking duration of *desi* and *kabuli* varieties is expected due to the thin seed coat of *kabuli* varieties. *Kabuli* varieties, viz. GLK 26155, PKV 4, IPCK 2002-29 and KAK 2 required only 1.5 hrs of soaking. *Kabuli* varieties, viz. CSJK 6, JGK 3 and HK 2 and *desi* varieties RVG 203, RSG 902, Vishal, GNG 2144, GBM 2, N BeG 47, Karnal Chana 1, GNG 469, Gujarat Gram 1, Digvijay, RSG 945, JG 16 and Gujarat Gram 2 required up to 3 hrs of soaking. Variety Kripa among *kabuli* group and JAKI 9218, RSG 973, RSG 963, JG 11, Vijay, JG 315, GPF 2, RVG 202, RVG 201, RSG 974, JG 130, Annigeri 1, C 235 and GNG 2171 among *desi* type required up to 4.5 hrs of soaking while *desi* varieties CSJ 515, GNG 1958, RSG 931, RSG 895, RSG 888, PBG 5, GNG 1581, Pusa 547, HC 5, Sadabahar and RSG 991 required up to 6 hrs of soaking as pre milling treatment. Large genotypic difference between soaking time within *desi* and *kabuli* varieties can be attributed to difference in seed coat, i.e. thickness, permeability to water etc. Wood *et al*. (2011) reported that the thinner seed coat in *kabuli* types is due to thinner palisade and parenchyma layers with fewer polysaccharides. Umaid *et al*. (1984) reported that the outermost layer (epidermis) in *kabuli* seeds develops into a uniseriate palisade layer without thickening of the cell wall while in *desi* chickpeas, it develops into a multiseriate

Table 2 Milling parameters among *desi* and *kabuli* varieties of chickpea

Variety	Soaking duration (min)	*Dal* recovery (%)	Chaff (%)	Grain yield (kg/ ha)	*Dal* yield (kg/ ha)	100 Seed Weight (g)
Desi varieties						
RVG 202	240	79.0	19	1833	1448	24.90
RVG 203	120	71.0	22	1740	1235	23.00
CSJ 515	330	71.7	26.2	2333	1673	16.10
GNG 1958	330	76.9	20.2	1373	1056	24.97
RSG 931	330	75.3	22.9	1600	1205	13.40
PBG 5	360	68.1	23.8	1427	972	14.20
RVG 201	240	78.9	19.3	1167	921	22.88
RSG 974	240	68.9	30.8	2558	1762	16.24
GNG 1581	360	68.7	26.1	811	557	15.11
Digvijay	180	82.6	13.5	1493	1233	21.76
JAKI 9218	195	71.2	18.1	2320	1652	15.92
RSG 973	195	74.1	22.6	2133	1581	17.90
Pusa 547	360	77.4	21.6	2147	1662	22.58
RSG 895	330	74.6	22.8	1553	1159	15.54
RSG 963	195	75.0	23	2400	1800	17.12
RSG 945	180	74.9	23.5	1840	1378	17.75
HC 5	360	69.4	25.7	2160	1499	16.77
RSG 888	330	77.7	21.4	881	685	14.63
JG 130	240	73.3	23	1927	1412	21.91
JG 16	180	71.9	20.4	1560	1122	16.68
Gujarat Gram 1	170	76.4	21.3	1440	1100	16.79
Gujarat Gram 2	180	79.2	18.3	1333	1056	25.74
JG 11	210	73.1	24.3	1773	1296	20.68
GNG 469	165	81.4	17.8	1333	1085	25.92
GPF 2	225	70.5	29	1220	860	14.32
Vijay	210	73.7	23.8	1556	1146	19.28
JG 315	210	72.5	25.9	1333	967	16.92
Annigeri 1	240	70.3	27.2	952	669	12.06
C 235	240	69.8	27.1	1867	1303	12.67
RSG 902	120	77.8	19.5	1760	1369	15.03
Vishal	120	61.3	21.3	1867	1144	20.85
GNG 2144	120	74.4	22.8	2420	1800	15.52
N BeG 47	135	78.5	19.6	1500	1178	26.53
GBM 2	120	79.0	17.3	1733	1369	17.38
Sadabahar	360	68.9	28.1	2433	1677	12.80
RSG 991	360	69.5	27.6	2200	1529	15.48
Karnal Chana 1	135	70.7	26.8	1064	752	13.52
GNG 2171	270	71.7	24.5	1400	1004	15.72
CD (P=0.05)	19.93	5.81	1.90	136.81	100.91	1.46

Cond.

Table 2 (*Concluded*)

Variety	Soaking duration (min)	*Dal* recovery (%)	Chaff (%)	Grain yield (kg/ ha)	*Dal* yield (kg/ ha)	100 Seed Weight (g)
Kabuli varieties						
IPCK 2002-29	90	86.3	9.6	1764	1522	33.18
JGK 3	150	87.4	10.1	1333	1165	23.47
HK 2	150	83.1	11.9	944	785	24.14
KAK 2	90	85.4	13.6	1111	949	36.98
CSJK 6	100	87.5	11.5	1686	1475	29.23
CD (P=0.05)	3.23	2.91	0.31	39.44	40.95	0.91

palisade layer which later becomes thick walled sclereids heavily stainable with toluidine blue, indicating the presence of phenolic compounds contributing to seed-coat colour. This would probably explain the easier dehulling properties of *desi* chickpea varieties than those of the *kabuli* varieties.

Dal *recovery* (%)

The *dal* recovery ranged from 61.3-82.6 % with average of 73.7% among *desi* types and 83.1-87.8% with average of 85.6% among *kabuli* types. Kurien (1984) reported 73-83% *dal* recovery among chickpea cultivars of Indian sub-continent region and predicted a maximum recovery potential of 88% depending upon the seed coat content. Others reported a *dal* yield ranging from 73-83% (Singh and Iyer 1998, Agrawal and Singh 2003).

Only two *desi* chickpea varieties, viz. Digvijay and GNG 469 and all the *kabuli* varieties under study, i.e. GLK 26155, CSJK 6, JGK 3, IPCK 2002-29, KAK 2, PKV 4, Kripa and HK 2 had more than 80% *dal* recovery (Table 2). Ten *desi* varieties viz.Gujarat Gram 2, RVG 202, GBM 2, RVG 201, N BeG 47, RSG 902, RSG 888, Pusa 547, GNG 1958 and Gujarat Gram 1 had 76-80% *dal* recovery while 17 others namely RSG 931, RSG 963, RSG 945, RSG 895, GNG 2144, RSG 973, Vijay, JG 130, JG 11, JG 315, JG 16, CSJ 515, GNG 2171, JAKI 9218, RVG 203, Karnal Chana 1 and GPF 2 had 71-75% *dal* recovery. Varieties Annigeri1, C 235, RSG 991, HC 5, RSG 974, Sadabahar, GNG 1581, PBG 5 and Vishal had less than 75% *dal* recovery. Thus some of the *desi* varieties had quite high *dal* recovery which will compensate for their lower yielding potential to some extent. Such a variation within *desi* and *kabuli* genotypes indicates that it is the property of a genotype and the ideal milling genotypes need to be worked out. Wood *et al.* (2008) observed large genotypic differences for the milling parameters among 8 cultivars and breeding lines grown over multiple sites and seasons with *dal* yield varying up to 16.6% between genotypes. Milling performance was largely independent of the growing environment although *dal* yield may be affected indirectly through *per se* yield of the genotype.

Chaff (%)

In our study, the chaff (%) of *desi* varieties ranged from 13.5-30.8% with mean value of 22.8% while it ranged from just 8-13.6% among *kabuli* varieties with mean value of 10.9%. All of the *kabuli* varieties and Digvijay, GBM 2, GNG 469, JAKI 9218, Gujarat Gram 2, RVG 202, RVG 201, RSG 902, N BeG 47 among *desi* varieties produces <20% chaff. On the other hand, *desi* varieties GNG 1958, JG 16, Gujarat Gram 1, Vishal, RSG 888, Pusa 547, RVG 203, RSG 973, RSG 895, GNG 2144, RSG 931, RSG 963, JG 130, RSG 945, PBG 5, Vijay, JG 11 and GNG 2171 had chaff recovery of 20-25% while HC 5, JG 315, GNG 1581, CSJ 515, Karnal Chana 1, C 235, Annigeri 1, RSG 991, Sadabahar and GPF 2 had 25-30% chaff content. *Desi* variety RSG 974 had more than 30% chaff content. It is argued that thick seed coat of *desi* varieties are adversely affecting the maximum *dal* recovery potential and work needs to be done to develop *desi* varieties having thin seed coat that is easily removed from the cotyledons to maximize *dal* yield. Agbola *et al*. (2002) reported that Australian *desi* types are usually preferred for splitting (*dal*) mainly due to their high *dal* yields, uniform size/shape and fewer impurities and these attributes also apply to *kabuli* types used for milling. Another observation in milling of *kabuli* types was that though milling was easy and chaff content was less, the quality of milled produce in terms of uniformity of removal of husk from cotyledons was poor. There have been reports that the adhesion of seed coat to cotyledons in chickpea is affected by non-starchy polysachharides present in the husk. Ramakrishnaiah and Kurien (1995) observed more than double amount of hexose and uronic acid of water soluble non starchy polysachharide fractions of husk in *kabuli* types as compared to *desi* ones which may lead to poor milling quality.

Grain and dal *yield*

The grain yield ranged from 811-2558 kg/ha with average of 1695.8 kg/ha among *desi* and 944-1764 kg/ha with average of 1267.6 kg/ha among *kabuli* type varieties. Agrawal and Singh (2003) reported a range of 3.5% in *dal* yield (67.58-71.08%) for eight *desi* Indian cultivars and noted that the smaller seeded varieties tended to have higher yields. *Kabuli* varieties HK 2, PKV 4, Kripa, KAK 2 and *desi* varieties GNG 1581, RSG 888, Annigeri 1, Karnal Chana 1 and RVG 201 were low yielding with yield levels ranging from 8-12 q/ha under Kanpur condition. The varieties GLK 26155, JGK 3 among *kabuli* group and GPF 2, Gujarat Gram 2, GNG 469, JG 315, GNG 1958, GNG 2171, PBG5, Gujarat Gram 1, Digvijay, N BeG 47, RSG 895, Vijay, JG 16 and RSG 931 among *desi* type provided relatively better yield at 12-16 q/ha. *Kabuli* varieties CSJK 6, IPCK 2002-29 and *desi* varieties GBM 2, RVG 203, RSG 902, JG 11, RVG 202, RSG 945, C 235, Vishal and JG 130 were better yielders (16-20 q/ha). *Desi* varieties RSG 973, Pusa 547, HC 5, RSG 991, JAKI 9218, CSJ 515, RSG 963, GNG 2144, Sadabahar and RSG 974 performed best attaining grain yield of more than 20 q/ha.

Table 3 Genetic parameters for milling properties of *desi* and *kabuli* varieties of chickpea

Parameter	Type	Mean	Range	Coefficient of variation		Heritability (Broad sense)	Expected genetic advance as % of mean
				Phenotypic (PCV)	Genotypic (GCV)		
Soaking duration (min)	*Desi*	233.8	120 - 360	35.72	35.33	0.98	71.99
	Kabuli	125.0	90 - 240	42.78	42.75	0.99	88.02
Dal recovery (%)	*Desi*	73.7	61.3 - 82.6	7.15	5.26	0.54	7.96
	Kabuli	85.6	83.1 – 87.8	2.74	1.94	0.50	2.82
Chaff (%)	*Desi*	22.8	13.5 - 30.8	16.76	15.96	0.91	31.3
	Kabuli	10.9	8 – 13.6	16.10	16.02	0.99	32.82
Grain yield (kg/ha)	*Desi*	1695.8	811 - 2558	27.56	27.11	0.97	54.94
	Kabuli	1267.6	944 - 1764	24.93	24.86	0.99	51.09
Dal yield (kg/ha)	*Desi*	1245.2	557 - 1800	26.61	26.14	0.97	52.89
	Kabuli	1089.2	785 - 1522	26.47	26.38	0.99	54.17
100 seed weight (g)	*Desi*	18.1	12.1 - 26.5	23.34	22.8	0.95	45.89
	Kabuli	34.6	23.5 - 61.9	38.42	38.39	0.99	79.02

The *dal* yield ranged from 557-1800 kg/ha with average of 1245.2 kg/ha among *desi* and 785-1522 kg/ha with an average of 1089.2 kg/ha among *kabuli* varieties. *Kabuli* varieties HK 2 and PKV 4 and *desi* varieties GNG 1581, Annigeri 1, RSG 888 and Karnal Chana 1 showed poor *dal* yield ranging from 4-8 q/ha. The varieties Kripa, KAK 2, GLK 26155 and JGK 3 among *kabuli* type and GPF 2, RVG 201, JG 315, PBG5, GNG 2171, GNG 1958, Gujarat Gram 2, GNG 469, Gujarat Gram 1, JG 16, Vishal, Vijay, RSG 895 and N BeG 47 among *desi* types gave relatively better *dal* yield ranging from 8-12 q/ha. *Kabuli* varieties CSJK 6 and IPCK 2002-29 and *desi* varieties RSG 931, Digvijay, RVG 203, JG 11, C 235, RSG 902, GBM 2, RSG 945, JG 130, RVG 202, HC 5, RSG 991 and RSG 973 showed better *dal* yield (12-16 q/ha). *Desi* varieties JAKI 9218, Pusa 547, CSJ 515, Sadabahar, RSG 974, RSG 963 and GNG 2144 gave highest *dal* yield of more than 16 q/ha.

The approximate *dal* yield based on yield performance of varieties and their *dal* recovery rate showed an interesting pattern. Many varieties that ranked higher in grain yield potential ranked relatively lower in *dal* yield due to poor milling recovery, e.g. *desi* chickpea varieties RSG 974 and Sadabahar which top two high grain yielding varieties were relegated to third and fourth place in terms of absolute *dal* yield. On the other hand, varieties GNG 2144 and RSG 963 which were relatively poor in grain yield were the top two higher *dal* yielding varieties. Thus GNG 2144 and RSG 963 should be preferred over RSG 974 and Sadabahar if the purpose of a grower is to use them for *dal* milling only. Thus *dal* recovery trait can be added to crop improvement goals in order to maximise the profit of the farmers rather than focussing just on increase in yield.

100 seed weight

The 100 seed weight ranged from 12.10-26.50 g with average of 18.10 g among *desi* and 23.53-61.99 g with average of 34.58 g among *kabuli* varieties. None of the *kabuli* varieties and eight *desi* varieties namely Annigeri 1, C 235, Sadabahar, RSG 931, Karnal Chana 1, PBG 5, GPF 2 and RSG 888 among *desi* varieties showed less than 15 g/100 seed weight. The *kabuli* varieties JGK 3, GLK 26155, HK 2 and *desi* varieties RSG 902, GNG 1581, RSG 991, GNG 2144, RSG 895, GNG 2171, JAKI 9218, CSJ 515, RSG 974, JG 16, HC 5, Gujarat Gram 1, JG 315, RSG 963, GBM 2, RSG 945, RSG 973, Vijay, JG 11, Vishal, Digvijay, JG 130, Pusa 547, RVG 201, RVG 203, RVG 202 and GNG 1958 had 100 seed weight ranging between 25-35 g. Chickpea varieties CSJK 6, IPCK 2002-29 among *kabuli* type and Gujarat Gram 2, GNG 469 and N BeG 47 among *desi* types had 100 seed weight of 25-35g. Varieties KAK 2, PKV 4 and Kripa among *kabuli* types and none of the *desi* varieties had 100 seed weight of more than 35 g. Thus, a large variability exists between *desi* varieties in terms of seed weight which can have an impact on the *dal* recovery. Seed size is a varietal trait and is affected by growing season and location (Williams and Singh 1987). The appropriate seed size for milling depends on equipments utilized and methodology followed. Very small seed tends to be difficult to mill while very large seed may cause excessive loss as broken seed. Usually uniform and medium sized seeds are preferred by pulse millers.

Genetic components of milling traits in chickpea

In general the phenotypic coefficients of variability was slightly higher than corresponding genotypic coefficients of variability for all the milling traits among both *desi* and *kabuli* varieties (Table 3). Moderate estimate of phenotypic and genotypic coefficients of variability was observed for all the traits except *dal* recovery which indicated presence of low variability (Table 3). Heritability and genetic advance as per cent of mean provides a clear picture of the scope

Table 4 Correlation among milling parameters in chickpea varieties.

Character	Type	*Dal* recovery (%)	Chaff recovery (%)	100 seed weight (g)
Soak time (hrs)	*Desi*	-0.212	0.401*	-0.275
	Kabuli	-0.523	-0.619	-0.264
Dal recovery (%)	*Desi*		-0.705**	0.521**
	Kabuli		-0.037	0.142
Chaff recovery (%)	*Desi*			-0.611**
	Kabuli			-0.291

** Significant at P = 0.01, * Significant at P = 0.05

for improvement in various quality traits through selection. The heritability (bs) was very high for all the traits except *dal* recovery (%). Low estimates of heritability (bs) for *dal* recovery (%) content indicated large environmental influence of the traits. Thus due to presence of less variability coupled with low heritability, little genetic advance is expected for *dal* recovery (%) among chickpea varieties by direct selection. There is a need for focussed research and intensified breeding for increasing the variability for *dal* recovery among chickpea genotypes through utilization of diverse genotypes.

Correlation among processing parameters

Among the chickpea varieties studied, the soaking time did not showed any association with *dal* recovery (%) and 100 seed weight although it showed significant positive association with Chaff recovery among *desi* types (Table 4). As the soaking time increased, the chaff recovery also increased among *desi* varieties and vice versa. Among *desi* types, the *dal* recovery showed significant positive correlation with 100 seed weight and significant negative correlation with chaff content. No such relation was observed in *kabuli* types. Among *desi* chickpea type, the seed weight acts as an indirect estimate of seed size. Thus, varieties having higher seed weight generally have larger seed size. Due to this, the milling operation becomes more effective leading to increased *dal* recovery. The seed of *kabuli* chickpeas are already larger in size compared to *desi* varieties and hence do not show significant effect of seed size variation on milling performance. Milling efficiency correlated negatively with seed size in green gram, cowpea and pigeon pea (Ehiwe and Reichert 1987, Singh *et al*. 1992). Williams *et al*. (1993) reported that increased seed size in lentils favour milling but very large size might cause heavy loss as broken seeds. The seed coat thickness varies among *desi* and *kabuli* types. The *kabuli* varieties have thin seed coats leading to less chaff content while *desi* types have relatively thicker seed coat and the chaff content also varies depending upon the seed size. The more the seed size of *desi* type, lesser will be the chaff content and vice versa. This is obvious from our study where the chaff recovery showed significant negative correlation with 100 seed weight among *desi* varieties (Table 4). Variation in seed coat content between varieties has been reported earlier (Kumar and Singh 1989) which significantly affect yield of milled produce. Thus there is a need to reduce the seed coat thickness among *desi* varieties for higher *dal* recovery.

Based on all the milling parameters, the chickpea varieties GNG 2144, RSG 963 and RSG 974 among *desi* and IPCK 2002-29, CSJK 6 and JGK 3 among *kabuli* types were best. These may serve as benchmark for further improving the milling efficiency of chickpea varieties grown in India.

Chickpea is the major pulse crop grown in Indian sub-continent and serves as an important source of protein to the population. Varietal differences have been observed for milling potential of chickpea varieties. Improvement in the milling potential of chickpea varieties can have a positive impact on overall *dal* production in the country. The present study provided current status of milling potential in popular chickpea varieties. Although *kabuli* types are mostly consumed as whole grain, they showed better milling recovery, lesser soaking time and less chaff content as compared to *desi* varieties indicating importance of thinner seed coat in improving milling potential. There is a need to reduce the seed coat thickness among *desi* varieties *vis-à-vis* increase in seed size for improving milling recovery. Currently many large seeded *desi* chickpea varieties are available but there is need to reduce their seed coat thickness. Moderate variation among milling parameters was observed among *desi* and *kabuli* varieties cultivated in the country which can be exploited for further quality improvement in chickpea.

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